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Water relations of *Banksia* woodlands

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Introduction

The interaction of the climate, soils and geology of the Swan Coastal Plain has an important bearing on the water relations of *Banksia* woodlands. The coastal plain experiences a dry Mediterranean climate (Beard 1981) with 5-6 dry months each year and receives 86% of annual rainfall between May and October. The deep, leached sands that support *Banksia* woodlands have an extremely low water holding capacity and, consequently, virtually no water is available from the top few metres of soil during the summer months. Paradoxically, the presence of groundwater, usually at several metres depth, provides a potentially unlimited water supply for those deep rooted plants capable of reaching it.

Water use by *Banksia* woodlands

Water use by *Banksia* woodlands and other native vegetation is estimated to return 70-90% of average annual rainfall to the atmosphere through evapotranspiration and therefore has a significant impact on the amount of water available to recharge the groundwater body. Net recharge of groundwater, estimated to vary from 9% to >30% of annual rainfall depending on location, is affected by plant water use since a) plants remove water from the soil profile, preventing that water - which arrived as rain - from reaching the groundwater body; and b) some plants with deep tap roots make direct use of groundwater. Net recharge is greatest at upland sites where the water table is many metres below ground surface, and virtually inaccessible to even the deepest root systems.

Rooting depth and root system morphology determine which source of water is utilized by plants. Excavation of the root systems of shrub and tree species from *Banksia* woodlands demonstrated a diversity of rooting types and a range of rooting depths (Grieve 1956, Dodd *et al* 1984). At Gnangara, shallow root systems that penetrated up to 1 m were the commonest, being found in 25 of the 43 shrub species examined, including *Acacia pulchella*, *Calytrix fraseri*, *Eriostemon spicatus*, *Bossiaea eriocarpa*, *Hibbertia* aurea, *H. helianthemoides* and several species of *Leucopogon*. Medium-depth root systems that penetrated 1-2 m were found in eight of the species, including *Gompholobium tomentosum*, *Scholtzia involucrata*, *Adenanthos cygnorum* and *Conostephium pendulum*. Woodland plants with shallow or medium depth root systems would depend on profile-stored water. Deep tap roots, potentially capable of reaching ground water, were found in 13 species, including *Banksia attenuata*. *B. menziesii* and *B. ilicifolia*. *Daviesia triflora*. *Jacksonia densiflora*. *Petrophile linearis*. *Calytrix flavescens*. *Melaleuca scabra*. *M. seriata* and *Stirlingia latifolia* (Dodd *et al* 1984). This diversity of rooting depths and morphologies allows virtually complete occupation of the soil profile and leads to exhaustion of soil moisture reserves by late summer.

The moisture requirements of a large number of *Banksia* woodland species have been defined by Havel (1968). The trees *Melaleuca preissiana*. *Eucalyptus marginata*. *Banksia littoralis* and *B. ilicifolia* occur in moist sites near swamps, in depressions and on lower dune slopes. *Banksia attenuata* and *B. menziesii* characterize the drier upper slopes and dune crests, while *E. todtiana* and *Nuytsia floribunda* show no distinct preference. Havel (1968) also defined a number of understorey species as indicators of particular combinations of site moisture characteristics, soil type and topography. The moisture requirements of the indicator species are reflected in the site conditions which they characterise.

Responses to annual fluctuations in water supply

The various seasonal patterns of transpiration and water stress which have been measured in a range of *Banksia* woodland trees and shrubs closely reflect plant rooting depths and, consequently, the nature and longevity of the water supply (Grieve 1956, Dodd *et al* 1984). At a site with a water table at 6-7 m depth, high transpiration rates and relatively low levels of water stress were measured throughout summer in the deep rooted *Banksia attenuata*. *B. menziesii*, *Stirlingia latifolia*, *Daviesia triflora* and *Petrophile linearis*, indicating continuous access to groundwater. *Eremaea pauciflora* and *Jacksonia densiflora* also showed these features until the abrupt onset of severe water stress in mid summer, which was due possibly to their roots losing contact with the falling water table. Deep rooted plants are not obligate users of groundwater, however, since some of the species exhibited reduced transpiration with relatively high levels of water stress during summer at other sites which lacked accessible groundwater (Grieve 1956, Grieve & Hellmuth 1970). Shallow rooted species generally showed severe water stress during summer, the early onset and severity reflecting the shallowness of the root system and the exhaustion of moisture reserves in the soils above the groundwater body (Dodd *et al* 1984). One consequence of these differences in water relations is that maximum transpiration occurs during spring and early summer in the understorey, but during summer in the canopy.

Responses of vegetation to changes in water availability

Havel (1968) demonstrated that soil moisture conditions and the degree of soil leaching are the main determinants of the composition of the vegetation of the Swan Coastal Plain. This study involved detailed measurements of species composition and plant cover at a large number of *Banksia* woodland sites on the northern Swan Coastal Plain in the mid-1960s, before the start of groundwater extraction and, therefore, constitutes a major base-line survey for subsequent ecological investigations. Havel's sites included nine transects which ran from swamp to dune crest, covering the range of topographical situations characteristic of the coastal plain. Four of these transects have been re-surveyed, first in 1976 (Heddle 1980) and at 1-3 year intervals subsequently, while several additional transects have been established to permit monitoring over a wider range of sites, including some close to groundwater pumping bores. Over the study period, since 1966, the Swan Coastal Plain has experienced a drought with 15 years receiving below average rainfall.

The results reveal certain trends in soil moisture conditions and in the vigour and composition of *Banksia* woodlands. There has been a reduction in soil moisture contents and a lowering of the water table on a regional scale throughout the coastal plain. At the same time, soils of the upper slopes and crests of dunes have remained relatively dry. This drying of coastal plain soils has been largely due to a reduction in annual rainfall. Land-use changes and groundwater pumping have also had an impact at some locations. Changes in vegetation include:

• a shift to drier types of vegetation with reductions in some tree and understorey species which tolerate wetter soils, *eg Eucalyptus marginata*, *Banksia littoralis*, *Hypocalymma angustifolium* and *Regelia ciliata*. This has been accompanied by replacement of older and larger trees with seedlings since 1966, as in *B. littoralis* and *B. ilicifolia*. Some trees, such as the paperbarks (*Melaleuca* spp), have responded to drought by producing additional stems. In contrast, at sites where soil moisture conditions have remained relatively stable, the composition and vigour of the canopy have been maintained.

• many species which tolerate drier soils or which are not site-specific in occurrence have maintained or increased their abundance. These include *Banksia attenuata*, *B. menziesii*, *Gompholobium tomentosum*, *Hibbertia subvaginata* and *Leucopogon conostephioides*.

• certain short-lived understorey species have declined, probably because of the lack of suitable conditions for germination and establishment.

Many of these changes had been predicted in earlier studies by Aplin (1976), Havel (1975) and Heddle (1980). The major cause of these changes in the *Banksia* woodlands has been the long-term drought which has caused a lowering of water table levels and has affected vegetation on a regional scale. The extraction of groundwater has added to these effects in sections of the Gnangara Mound.

Responses to ground water extraction

Many of the vegetational changes likely to be associated with groundwater pumping have already been observed as responses to long-term, regional drought. The major differences would relate to the rapidity, extent and permanence of ground water draw-down, which would affect the banksias and a number of the understorey species. The majority of species are independent of groundwater, however, and should be little affected by pumping. Even where adult trees are killed, replacement from seed and from suppressed seedlings will occur, leading eventually to restoration of woodland. The resulting vegetation would probably have fewer and smaller trees and would resemble undisturbed woodland on dry, upland sites. In order to predict the effects of groundwater extraction and water table lowering in greater detail, further information is needed on the extent of groundwater use by the plants of the Swan Coastal Plain.

Conclusions

Plant species of the *Banksia* woodlands exhibit a variety of physiological responses to changes in water availability. Amongst many understorey species, the intensity of water stress is inversely related to rooting depth. This relationship does not hold for the canopy banksias and certain deep rooted shrubs which utilize groundwater at some sites and which are independent of soil-stored moisture. Knowledge of the water relations of plants from *Banksia* woodlands provides insights into the adaptations of plants in a Mediterranean-type environment and has helped explain the results of long-term monitoring, which in turn can be used for predicting the changes likely to occur in vegetation of the Swan Coastal Plain as a result of continuing droughts and/or increased groundwater extraction. Water use by existing vegetation is a major component of the water balance of the Swan Coastal Plain and is, therefore, of direct relevance to planning the development and management of the plain's groundwater resources.

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